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Title of the article: **Does physical fitness predict future karate success: a study in young female karatekas**

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Abstract

Objective: This study was aimed at assessing the discriminative ability of several fitness dimensions and anthropometric attributes for forecasting competitive success in female karate athletes.

Methods: Fitness and anthropometric data from 98 female junior karatekas obtained during the training camps of the Spanish National Karate Federation between 1999 and 2012 was used. Binary logistic regression models were built in order to ascertain whether the set of fitness and anthropometric variables could predict future sporting performance levels. For this purpose, participants were classified as elite (medalist in World or European Championships in senior category) or sub-elite (at least medalist in Spanish National Championships in cadet or junior but not included in the elite group), according to the results achieved up to 2019.

Results: Participants who were subsequently classified as elite karatekas showed significant differences in agility, upper and lower-body muscle power, and general fitness in comparison to those who were classified as sub-elite in senior category. A total of 57 junior female karatekas that were subsequently classified as elite (7) or sub-elite (50) were included in the binary logistic regression analysis. Resultant models showed significant capacity to predict karate performance.

Conclusion: Assessing physical fitness in junior categories can be a useful resource to determine future karate success. Coaches in this sport should pay special attention to the levels of muscular power and agility shown by their athletes, as both fitness dimensions are the ones that could be indicators of future sportive success.

Key words: talent selection, training, coaching, performance, martial arts, combat sports

Introduction

Karate, a martial art that is practiced worldwide, is currently considered one of the most popular and attractive combat sports[1]. Consequently, karate will make its first appearance in the Olympic Games program at Tokyo 2020, with men and women competing in kumite (combat) and kata (forms) events.

Success in Karate is influenced by physical, physiological and technical sport-specific skills, as well as tactical and perceptual-cognitive skills[2]. Therefore, the majority of the studies that have been published so far have focused mainly on describing the physical and physiological profile of the karatekas[3,4], as well as their technical attributes and tactical behavior[5]. However, a deficit continues to exist in research into karate.

Moreover, most research has been exclusively carried out with male karatekas[6,7,8], which underlines the need for more research focusing on female athletes[3]. Secondly, and equally important, there is a need to understand the main fitness and anthropometric factors that could determine the future success or failure of a karateka. Knowing the indicators that can help to discriminate between future elite and non-elite competitors will enable coaches to design training programs aimed at improving performance and facilitate the path to elite competition in young karatekas.

In spite of this, studies that have tried to identify the fitness and anthropometric indicators that can help to predict international competitive success at a senior level in karate are almost non-existent. This goal can be achieved through predictive models that can identify an optimal profile for karatekas seeking to perform at the highest international level. However, to the best of our knowledge very few studies that have focused on combat sports have applied these types of models and the majority of them included judo[9] and Olympic wrestling[10] fighters with no previous studies including karate athletes.

Thus, in the light of all this, this research aims at assessing the discriminative ability of several fitness dimensions and anthropometric attributes for forecasting competitive success in female karate athletes.

Methods

Participants

The present study was conducted by analyzing the data from the fitness and anthropometric assessment of junior category (16-17 years-old) female karate athletes during the training camps held by the Spanish National Karate Federation. All the female athletes who participated in these training camps between 1999 and 2012 were included in the study and an average value for each athlete in each variable was calculated when they attended to more than one training camp. In order to be selected for these camps, the female karatekas had to achieve at least a medal in one of the two previous Spanish National Championships in cadet (14-15 years-old) or junior (16-17 years-old) categories. The study complied with the Declaration of Helsinki and approval was granted by the Spanish National Karate Federation to analyze and publish the pre-existing collected data.

Anthropometrics

Anthropometric measurements were performed in a fasting situation, early morning before breakfast. Body mass and height were measured following standardized procedures to the nearest 0.5 cm and 0.1 Kg, respectively, and body mass index (BMI) was calculated as body mass in kilograms divided by square of height in meters (kg/m^2).

Body fat percentage (BF%) was calculated using the Slaughter et al.[11] formula that takes into account two skinfolds. BF% = 1.33 × Σ2 – 0.013 × $\Sigma 2^2$ – 2.5 where Σ2 is the sum of triceps and subscapular skinfolds.

Fitness

A selection of tests from the Eurofit battery[12] were used to evaluate the following fitness components: aerobic fitness (20-m shuttle run); lower-body muscular power (standing long jump); coordination and speed of upper limb movements (plate tapping test); agility (10 × 5-m shuttle run test); flexibility (sit-and-reach test). To assess upper-body muscular power, a two-handed overhead medicine ball throw (3 kg) was performed[13]. All the test measurements were carried out by a skilled Sports Scientist who had been an elite karate athlete and was specialized in conditioning testing of young athletes.

Sporting performance

In order to determine the level of sporting performance achieved by the female karatekas, results until 2019 were used to ascertain their best performance during their career in the adult category (senior). This information was obtained from the European and World Karate Federations official websites. Participants were allocated to one of these groups:

- Elite: athletes who achieved the very top level in karate in the senior category. The criterion in this study was to be medalist in World or European Senior Championships.
- Sub-elite: athletes who performed at high-level in karate but did not achieve the very top level in senior category. In this study all participants were at least medalists in Spanish National Cadet or Junior Championships, but those classified as sub-elite did not achieve a medal in a World or European Senior Championship.

Statistical analysis

A *total fitness score* was calculated for each participant following previous research that used a similar fitness battery[14]. All the fitness variables were converted to standardized scores [z = (athlete value – mean) / standard deviation] and then transformed in such a way that the positive value corresponded to better performance in the test. Finally, a constant of 10 to avoid negative values was added to the sum of all transformed z values. Thus, a new variable that ranged from 4.08 to 17.46, with a mean of 10.04 and a standard deviation of 3.16, was used to ascertain the global fitness level of each athlete. A prediction model of the future sporting performance in the adult category for female karatekas aged 16-17 was applied based on their former fitness and anthropometric variables. Prior to the main analysis, a one-way ANOVA (modality: kata vs kumite) was calculated to ascertain differences between kata and kumite specialists in order to determine if the sample would have to be segmented by modality. Mean and standard deviation were calculated for each sample group. Differences between elite and sub-elite female karatekas were ascertained by a one-way ANOVA (sporting level: elite vs sub-elite). To determine the difference level between modality and sporting level groups, Hedge's g effect sizes were calculated for each anthropometric and fitness variable, taking group sizes into account. Effect sizes were interpreted using Hopkins[15] scale: <0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large and 2.0–4.0 very large.

Binary logistic regression models were built to determine whether the set of fitness and anthropometric variables evaluated at 16-17 years old might predict future sporting performance levels in the adult category, following previous research into football[16] and Olympic wrestling[10]. This analysis included only those athletes that completed all the fitness and anthropometric assessment, i.e., one value for each variable. Sporting performance level was considered as the dependent variable. Thus, in the binary logistic regression, to be an elite female karate athlete was coded as "1" and sub-elite was coded as "0". Prior to this analysis, a Chi-square test was calculated to check the differences in frequencies between kata/kumite and elite/sub-elite. This was done in order to determine whether modality (kata/kumite) should be included as an independent variable in the model. Three different models were built, one including all the variables (model 1), another that included only those variables with significant differences between elite and sub-elite groups (model 2) and a third model including only variables that significantly contributed to the model 2 (model 3). In order to evaluate the models, the predicted values of group membership, the Nagelkerke R Square, the Omnibus Test of Model Coefficients and the Hosmer-Lemershow goodness-of-fit test were calculated. All statistical analysis was performed using SPSS 22. Significance level was set at $p < 0.05$ for all the analysis.

Results

Valid information was obtained from 98 female karate athletes (aged 17.04±0.47 years). All of them had achieved at least one medal in cadet (14-15 years) or junior (16-17 years) category in the Spanish National Karate Championships. According to the results subsequently obtained during their career in senior category (absolute), 14 participants were classified as elite and 84 as sub-elite.

Mean values obtained in the fitness test by female karate athletes grouped by modality are shown in Table 1. Differences between kata and kumite athletes were not significant, with the exception of height and aerobic fitness. Effect size differences were trivial or small, with the exception of these two variables, which were moderate.

Table 2 shows the comparison of fitness tests performed by female karate athletes when they were juniors. Those who were later classified as elite karatekas showed significant differences in agility, arm power, leg power and total fitness score with respect to sub-elite karatekas. Effect sizes were trivial or small for most of the variables, with the exception of leg power and total fitness scores, where they were moderate and arm power and agility, where they were large.

A total of 57 junior female karatekas later classified as elite (7) or sub-elite (50) completed the entire battery of 10 tests and so were included in the binary logistic regression analysis that is shown in Table 3. Karate modality (kata/kumite) and sporting performance (elite/sub-elite) showed not to be associated (Chi-square = 3.267, p = 0.071) and thus modality was not included in the model. Resultant models were valid to predict future karate performance from fitness tests and anthropometrics. Evaluation of the models showed significant results by Chi-square in the Omnibus Test of Model and the Hosmer-Lemershow goodness-of-fit test (Model 1: Chi-square = 0.000, df = 8, sig. = 1.000; Model 2: Chi- square = 5.415, df = 8, sig. = 0.712; Model 3: Chi-square = 13.014, df = 8, sig. = 0.111). As a whole, model 1 correctly predicted 100% of the cases, from 88.2% in the null model. It explained the 100% in variance (Nagelkerke R2 = 1.000). The contribution of each variable to the model 1 was not statistically

significant. Model 2 correctly predicted 87.7% of cases, from 87.7% in the null model. It explained the 29.2% in variance (Nagelkerke R2 = 0.292). Finally, model 3 correctly predicted 86.8% of cases, from 86.8% in the null model. It explained the 22.1% in variance (Nagelkerke R2 = 0.221). The agility test significantly contributed to the model 2 and model 3 predictions.

Discussion

This study was designed to address the question of which physical fitness and anthropometrical markers could lead to future sporting success for elite female junior karatekas. Data from the present study provide information and guidance for talent identification, fitness testing or training interventions in young female karatekas.

A first finding worthy of mention is the fact that hardly any differences were observed between kata and kumite athletes, with the exception of height and cardiorespiratory fitness. Anthropometric differences between the two modalities have previously been reported[17]. In relation to cardiorespiratory fitness, Doria et al, [18] despite not finding significant differences in maximum oxygen consumption between the practitioners of the two modalities, suggested that kumite performances are more demanding of aerobic energy, especially during simulated competitions. This may be the reason why the kumite practitioners in this study showed greater cardiorespiratory fitness.

When the karatekas in this study were tested in their junior years, it was observed that those that later reached elite success showed a higher fitness level at baseline. In other combat sports such as Judo, it was reported that junior and senior elite women did not differ in their fitness level[19]. In addition, Drid et al[20] reported that fitness profile was an indicator of senior elite success in this sport. Therefore, it could be hypothesized that in female karatekas, the level of general fitness could be considered as an indicator of athletic success in the senior years, provided that their physical performance capacity did not experience significant changes. Future investigations aimed at identifying the existing differences between the fitness level of junior and senior karatekas are needed to confirm this assumption.

In our study, when analyzing each physical fitness dimension separately, significant differences were found in upper and lower-body muscular power and agility. These results imply that both fitness dimensions seem to play an important role in the performance of this sport. In combat sports it is essential to have outstanding power since it allows for rapid and explosive displacements, punches and kicks. Consequently, it has been suggested that in karatekas upper- and lower-body muscle power strongly contributes to competitive performance[21]. Regarding our observations in relation to the influence of agility in karate performance, it is worth mentioning that similarly to our study, Katić et al[22] reported that explosive power and agility were the greatest determinants of fighting efficacy of female cadet karatekas. These findings highlight the importance of assessing agility when determining the fitness level of young karatekas.

We should also acknowledge that, according to our findings and contrary to Katić et al[22] observations, frequency of movements was not shown as a dimension of fitness determining future performance; this could suggest that from the junior category the margin for improvement could be reduced. We propose that in future studies aimed at identifying fitness levels in high level karatekas, speed of movements should be

assessed by means of specific tests that use karate movements where differences between participant skill levels are evident[23].

One of the major challenges confronting coaches and athletes is understanding the main physiological factors contributing to the success or failure of a karateka at a young age[3]. For this purpose, it is useful to apply models of prediction of sporting success, as is the case with this study. From the findings obtained, it can be inferred that the level of physical fitness shown in the junior category is an indicator of future sporting success, an idea previously suggested by other authors regarding combat sports[24].

It is well known that muscular strength (together with speed) is the most important fitness dimension required for senior karate performance[18,25]. This is because the decisive actions during karate are mainly dependent on explosive muscular power[3]. Therefore, it is not surprising that the results obtained in the upper and lower-muscular power tests were considered as indicators of future sporting success. In fact, other authors have also reported the existence of a correlation between muscular power and competitive level in karatekas. For instance, Roschel et al[25], showed that both upper- and lower-body muscle power were higher in winners as compared with defeated international level karatekas. Similarly, Ravier et al[26] found that the explosive strength (assessed by means of force-velocity and jump tests) of international karate athletes was about 14% higher than that of national athletes. In relation to the role that agility plays in performance success, no previous studies have been found that analyzed the importance of this fitness dimension in karatekas. However, Markovic et al[27] found, as in this study, that agility was one of the fitness dimensions that helped to distinguish the successful from the less successful athletes who practiced taekwondo.

Another finding of this research, that is in line with what has previously been suggested by other authors, is that cardiorespiratory fitness was not shown as a fitness dimension that could condition future sporting success. These results coincide with those reported by Ravier et al[28], who found no significant differences in aerobic performance between international and national karatekas. Therefore, the present findings contribute to the idea that cardiorespiratory fitness, although important in combat sports, is not usually a dimension of fitness that helps differentiate between higher and lower level athletes[4].

Practical Applications

This research indicates that two fitness components, explosive strength and agility, are of major importance for predicting sporting success in female karatekas. Therefore, karate coaches and trainers should pay special attention to those athletes who obtain high scores in field-based tests aimed at assessing both of these components, since they can indicate potentially successful elite competitors.

In spite of this, studies that have tried to identify the fitness and anthropometric indicators that can help to predict international competitive success at a senior level in karate are almost non-existent. Consequently, it was not known which fitness and anthropometric attributes can help to discriminate those athletes with higher probability of success.

The present research has its strengths and weaknesses. Its originality is a strong point, since, to the very best of the authors' knowledge, no research focused on predictive models of sporting success in karatekas has been published so far. The considerable sample size, the very high standard of the karatekas included in the research, and the

fact that the study focused specifically on female karatekas should also be highlighted. Another strong point worth mentioning is the external responsiveness shown by the simple fitness tests carried out, since they can be useful for a possible selection of talents as well as to discriminate among athletes of different competitive levels[1]. This is a noteworthy aspect, given that the need to find tests that are easy to perform and that provide information of interest to both karatekas and their coaches has been indicated[29].

In this study we focused on junior karatekas, since success in this category could be related with future senior performance. However, we could not perform a complete follow-up of all the participants in this study once they left the training camps. Therefore, there could have been other reasons that could help to explain why some of the junior karatekas did not reach senior success (injuries, motivation, family support, etc). Apart from that, we should also acknowledge that the anaerobic power level of the athletes was not evaluated. Although it has been considered that the main source of energy used by karatekas during combat comes from aerobic metabolism, the fact that anaerobic lactic power may be a physiological variable that also contributes to sporting success in this sport has not been ruled out[28]. Additionally, no other variables were recorded that influence the way to the top of the sporting ladder, such as the age at the time of competition debut or the level of motor ability, which largely determines the possibility of mastering karate technique and therefore fighting success[22].

Conclusions

The present study is one of the first studies of female karatekas to indicate that the assessment of physical fitness in junior categories can be a useful resource with regard to determining future sporting success. Karate coaches should pay special attention to the levels of muscular power and agility shown by their athletes, as both of these fitness dimensions could be indicators of future sporting success.

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Table 1: Descriptive values (mean and standard deviation) of female kata and kumite specialists. Differences between modality groups are shown as p (p value of ANOVA) and g (Hedge's g Effect Size).

	kumite			kata			Modality differences	
	N	Mean	SD	N	Mean	SD	p	g
Anthropometrics								
Weight (Kg)	53	55.68	7.2	28	52.68	6.3	0.07	0.4
Height (cm)	54	161.5	7.2	30	156.1	4.9	**0.00**	0.8
BMI (kg/m^2)	53	21.35	2.2	28	21.6	2.0	0.62	-0.1
BF%	37	26.79	2.8	20	27.34	3.1	0.59	-0.2
Fitness								
Sit and reach (cm)	62	28.24	7	30	29.07	5.6	0.57	-0.1
20-m shuttle run (min)	51	6.99	1.3	23	6.01	1.2	**0.00**	0.8
Standing long jump (cm)	54	186.3	17	26	185.6	17	0.86	0.0
Overhead 3Kg ball throw (m)	60	5.38	0.7	31	5.20	0.7	0.27	0.2
10x5 shuttle run (sec)	44	19.27	1.5	24	19.2	1.6	0.85	0.0
Plate tapping (sec)	39	9.30	0.8	21	9.33	1.0	0.90	0.0
Total fitness score	36	11.06	4.1	21	9.61	3.7	0.49	0.4

Table 2: Descriptive values (mean and standard deviation) of female karate athletes grouped by sporting performance level: elite and sub-elite. Differences between groups are shown as p (p value of ANOVA) and g (Hedge's g Effect Size).

	Elite			Sub-elite			Group differences	
	N	Mean	SD	N	Mean	SD	p	g
Anthropometrics								
Weight (Kg)	11	56.61	6.4	70	54.34	7.1	0.32	0.32
Height (cm)	12	161.2	6.5	72	159.3	7	0.37	0.28
BMI (kg/m^2)	11	21.75	1.7	70	21.39	2.2	0.6	0.17
BF%	7	28.47	1.8	55	26.79	3	0.28	0.59
Fitness								
Sit and reach (cm)	12	30.1	6.3	80	28.27	6.6	0.37	0.28
20-m shuttle run (min)	11	6.735	1.4	63	6.683	1.4	0.91	0.04
Standing long jump (cm)	11	196.3	15	69	184.4	17	**0.03**	0.72
Overhead 3Kg ball throw (m)	11	12	13	78	5.257	0.7	**0.03**	1.51
10x5 shuttle run (sec)	9	17.85	1.2	59	19.46	1.5	**0.00**	-1.11
Plate tapping (sec)	7	8.975	0.7	53	9.362	0.9	0.26	-0.45
Total fitness score	7	12.84	3.2	50	9.861	3.4	**0.02**	0.9

Table 3: Results of the logistic regression model of anthropometrics and fitness variables that were used to predict the sporting level for female karate athletes (N=57: 7 elite, 50 sub-elite). The dependent variable is to be in the "elite" group: medalists in European or World Championships in the absolute category.

Predictor	Model 1				Model 2				Model 3			
	B	S.E.	Exp(B)	Sig.	B	S.E.	Exp(B)	Sig.	B	S.E.	Exp(B)	Sig.
Constant	958.441	3719143.315	0.000	1.000	1.781	7.975	5.935	0.823				
Weight (Kg)	-1.236	35998.083	0.291	1.000								
Height (cm)	1.782	24937.900	5.944	1.000								
BMI	-15.752	91854.409	1.4422E-07	1.000								
BF%	9.315	3830.323	11101.844	0.998								
Sit and reach (cm)	3.972	1856.622	53.110	0.998								
20-m shuttle run (min)	-0.662	7331.545	0.516	1.000								
Standing long jump (cm)	-3.465	1544.472	0.031	0.998	0.019	0.035	1.019	0.580				
Overhead 3 Kg ball throw (m)	78.732	16496.264	1.5588E+34	0.996	0.950	0.605	2.586	0.116				
10x5 shuttle run (sec)	-46.415	12998.648	6.9534E-21	0.997	-0.679	0.330	0.507	0.039	-0.716	0.261	0.489	0.006
Plate tapping (sec)	-15.963	7649.271	1.1681E-07	0.998								
Chi-square	24.63 (df = 10) (sig. = **0.006**)				9.51 (df = 3) (sig. = **0.023**)				8.67 (df = 1) (sig. = **0.003**)			
Cases correctly classified	100%				87.7%				86.8%			

Null models based on 88.2% of elite karateka in model 1, 87.7% in model 2 and 86.8% in model 3.